# Power Flow comparison between Typhoon HIL and Matpower

This document describes the tools, models, assumptions and other details regarding the power flow calculation and comparison, and show results for different set-points and considerations. We begin by describing the tools.

The model that we want to compare was executed in Typhoon HIL software version 2016.4 via VirtualHIL application. The choice of using VirtualHIL instead of hardware HIL was based on the possibility of setting the signal processing (SP) execution rate equal to the power electronics simulation time-step, which allows us to get increased measurement precision while not making the system unstable (instabilities would happen if hardware HIL was used with that SP execution rate). To measure voltage magnitude and phase angle, phase-to-phase voltage measurements were applied in each bus between phases A and B. The waveform measured was sent to a “Single Phase Phasor” SP block which calculated voltage magnitude and angle by comparing it to the reference set (Bus1).

The power flow calculation was done with a free Matlab application named Matpower and developed by Ray D. Zimmerman and Carlos E. Murillo-Sanchez. One can download the application through the website: <http://www.pserc.cornell.edu/matpower/>.

The model used for the comparison is the Feeder 1 from the Banshee model developed by Lincoln Lab and implemented by Typhoon HIL in its own software for the Microgrid & DER Controller Symposium. To make the power flow calculations easier to implement in both platforms, a few assumptions and modifications had to be made. First, all transmission lines were changed to RL (resistive-inductive) only, i.e. the inductive mutual coupling and the capacitance effects were not considered. Second, the Diesel Genset and its control, fully implemented in Typhoon HIL, was left to be the same in Typhoon’s platform, while in Matpower the genset was implemented as a power injection in the respective bus (bus16). This means that all impedances from the synchronous machine were unconsidered (all the impedances outside of the synchronous machine were implemented). The 200HP motor was replaced by a RL load with equivalent power. Bus 1 was considered in both cases to be an infinity bus, i.e. it can supply or absorb any amount of power needed by the system. All unnecessary elements in Typhoon HIL implementation were removed to speed the analysis process.

The picture below shows the Feeder 1 topology and the bus number designation used.

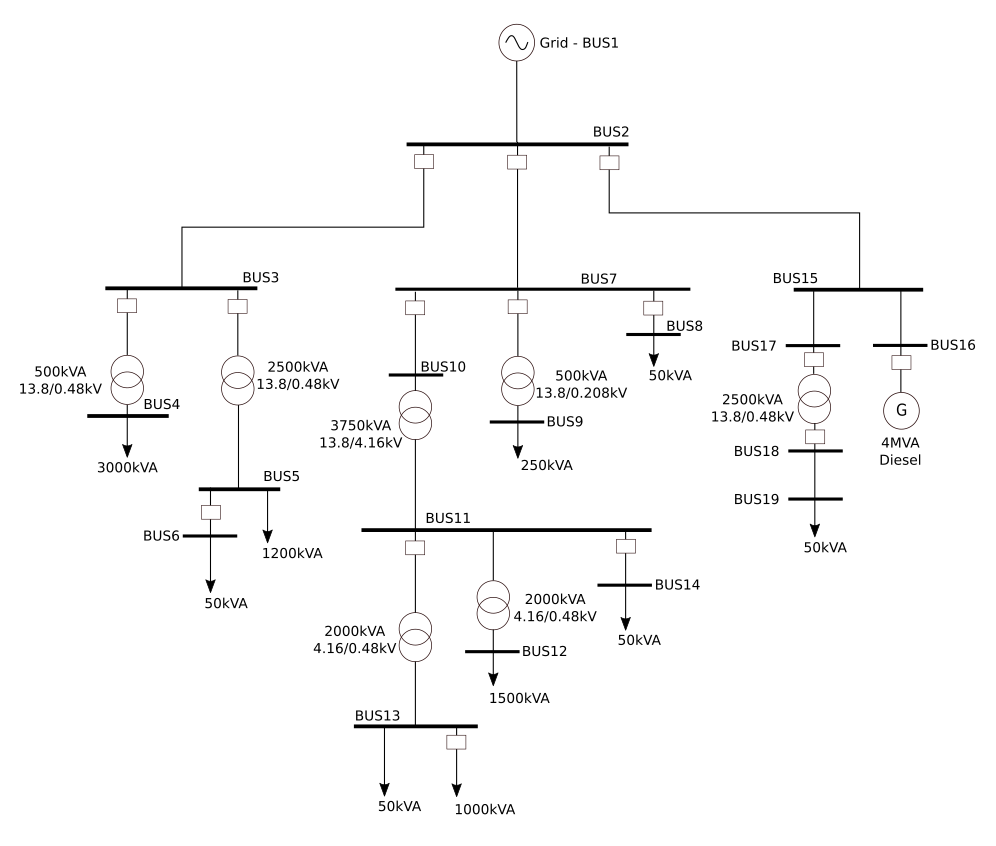


Figure 1 - Feeder 1 topology and bus number assignment

To use Matpower, all the circuit impedances were converted to PU using as voltage base the nominal voltage of each zone and as power base the randomly picked value of 3.5MVA. Transformers magnetizing induction losses were implemented as shunt susceptances, while magnetizing resistance losses were implemented as shunt constant impedance loads on the primary sides of the transformers. All loads were implemented as shunt constant impedance loads with a power factor of 0.9. Impedances used to create neutral points for measurements or used as snubbers where implemented as shunt constant impedance loads. To understand how to fill Matpower’s matrices, refer to their manual available online or with their tool. Attached at the end of this document is the script used to calculate the impedances and loads.

Different comparisons were made between the two platforms. First, four different cases were created in Matpower. They are:

* Case 1 – No measurement resistors and no snubber impedances were considered. The respective Matlab script named Feeder1BansheeSimple.m is attached at the end.
* Case 2 – No measurement resistors implemented and all snubber impedances considered. The respective script named Feeder1Banshee.m is attached.
* Case 3 – All measurement resistors are implemented and no snubber impedances are considered. The respective script named Feeder1BansheeNoSnubbers.m is attached.
* Case 4 – All measurement resistors and all snubbers are implemented. The respective script named Feeder1BansheFULL.m is attached.

Without changing Typhoon HIL schematic, data was captured in two ways. One with the Diesel Genset (DG) operating and active and reactive power control (PQ mode), where the power set-points were defined exactly as in the power flow from Matpower; and one with the DG operating in voltage and active power control (PV mode), where the active power set-point is the same as in Matpower and the voltage is set to be nominal at the bus 16. In other words, there is five cases with data captured from Typhoon: four in PQ mode and one in PV mode. Eight comparison were done with the data captured. Part of the results are shown below.

Table 1 - Voltage magnitude and phase angle comparison between the four cases in Matpower

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | Vmag | Vmag | Vmag | Vmag |  | Vphase | Vphase | Vphase | Vphase |
| 1 | 1 | 1 | 1 | 1 |  | 0 | 0 | 0 | 0 |
| 2 | 0.998 | 0.998 | 0.998 | 0.998 |  | 0.023 | 0.019 | 0.022 | 0.018 |
| 3 | 0.996 | 0.996 | 0.996 | 0.996 |  | -0.004 | -0.008 | -0.005 | -0.009 |
| 4 | 0.993 | 0.994 | 0.993 | 0.994 |  | -30.185 | -30.189 | -30.186 | -30.19 |
| 5 | 0.985 | 0.985 | 0.985 | 0.985 |  | -30.85 | -30.854 | -30.852 | -30.855 |
| 6 | 0.952 | 0.952 | 0.952 | 0.952 |  | -31.25 | -31.254 | -31.252 | -31.255 |
| 7 | 0.985 | 0.985 | 0.985 | 0.985 |  | -0.103 | -0.127 | -0.106 | -0.13 |
| 8 | 0.985 | 0.985 | 0.985 | 0.985 |  | -0.105 | -0.128 | -0.108 | -0.132 |
| 9 | 0.983 | 0.983 | 0.983 | 0.983 |  | -30.254 | -30.278 | -30.257 | -30.281 |
| 10 | 0.981 | 0.982 | 0.981 | 0.982 |  | -0.134 | -0.164 | -0.137 | -0.167 |
| 11 | 0.964 | 0.964 | 0.964 | 0.964 |  | -31.749 | -31.779 | -31.753 | -31.783 |
| 12 | 0.951 | 0.951 | 0.951 | 0.951 |  | -62.803 | -62.833 | -62.807 | -62.837 |
| 13 | 0.954 | 0.954 | 0.954 | 0.954 |  | -62.559 | -62.59 | -62.563 | -62.593 |
| 14 | 0.963 | 0.963 | 0.963 | 0.963 |  | -31.76 | -31.79 | -31.764 | -31.794 |
| 15 | 0.999 | 0.999 | 0.999 | 0.999 |  | 0.105 | 0.1 | 0.104 | 0.099 |
| 16 | 1 | 1 | 1 | 1 |  | 0.318 | 0.317 | 0.315 | 0.315 |
| 17 | 0.999 | 0.999 | 0.999 | 0.999 |  | 0.104 | 0.1 | 0.103 | 0.098 |
| 18 | 0.998 | 0.998 | 0.998 | 0.998 |  | -29.929 | -29.934 | -29.931 | -29.935 |
| 19 | 0.933 | 0.933 | 0.932 | 0.933 |  | -30.703 | -30.707 | -30.704 | -30.709 |

Table 2 - Active and Reactive power comparison between each case in Matpower

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | P | P | P | P |  | Q | Q | Q | Q |
| 1 | 2.55 | 2.55 | 2.59 | 2.59 |  | 3.09 | 2.9 | 3.08 | 2.89 |
|  |  |  |  |  |  |  |  |  |  |
| 16 | 1.5 | 1.5 | 1.5 | 1.5 |  | -0.98 | -1.1 | -0.97 | -1.09 |

Table 3 - Voltage magnitude and phase angle comparison between each case in Typhoon HIL (PQ mode)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | Vmag | Vmag | Vmag | Vmag |  | Vphase | Vphase | Vphase | Vphase |
| 1 | 1.000 | 1.000 | 1.000 | 1.000 |  | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 0.999 | 0.999 | 0.999 | 0.999 |  | -0.086 | -0.086 | -0.086 | -0.086 |
| 3 | 0.996 | 0.996 | 0.996 | 0.996 |  | -0.173 | -0.173 | -0.173 | -0.173 |
| 4 | 0.984 | 0.984 | 0.984 | 0.984 |  | -31.023 | -31.023 | -31.023 | -31.023 |
| 5 | 0.985 | 0.985 | 0.985 | 0.985 |  | -30.936 | -30.936 | -30.936 | -30.936 |
| 6 | 0.952 | 0.952 | 0.952 | 0.952 |  | -31.368 | -31.368 | -31.368 | -31.368 |
| 7 | 0.985 | 0.985 | 0.986 | 0.985 |  | -0.259 | -0.259 | -0.259 | -0.259 |
| 8 | 0.985 | 0.985 | 0.985 | 0.985 |  | -0.259 | -0.259 | -0.259 | -0.259 |
| 9 | 0.975 | 0.975 | 0.975 | 0.975 |  | -31.023 | -31.023 | -31.023 | -31.023 |
| 10 | 0.982 | 0.982 | 0.982 | 0.982 |  | -0.259 | -0.259 | -0.259 | -0.259 |
| 11 | 0.971 | 0.970 | 0.971 | 0.970 |  | -31.368 | -31.368 | -31.368 | -31.368 |
| 12 | 0.954 | 0.954 | 0.954 | 0.954 |  | -62.736 | -62.736 | -62.736 | -62.736 |
| 13 | 0.958 | 0.958 | 0.958 | 0.958 |  | -62.304 | -62.304 | -62.391 | -62.304 |
| 14 | 0.970 | 0.970 | 0.970 | 0.970 |  | -31.368 | -31.368 | -31.368 | -31.368 |
| 15 | 0.999 | 0.999 | 0.999 | 0.999 |  | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | 1.000 | 1.000 | 1.000 | 1.000 |  | 0.202 | 0.259 | 0.173 | 0.259 |
| 17 | 0.999 | 0.999 | 0.999 | 0.999 |  | -0.086 | -0.086 | -0.086 | -0.086 |
| 18 | 0.998 | 0.998 | 0.998 | 0.998 |  | -30.072 | -30.072 | -30.072 | -30.072 |
| 19 | 0.933 | 0.933 | 0.933 | 0.933 |  | -30.850 | -30.850 | -30.850 | -30.850 |

Table 4 - Active and Reactive power comparison between each case in Typhoon HIL (PQ mode)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | P | P | P | P |  | Q | Q | Q | Q |
| 1 | 2.594 | 2.594 | 2.594 | 2.594 |  | 2.818 | 2.909 | 2.737 | 2.879 |
|  |  |  |  |  |  |  |  |  |  |
| 16 | 1.500 | 1.500 | 1.500 | 1.500 |  | -1.041 | -1.130 | -0.960 | -1.101 |

Table 5 - Voltage magnitude and phase angle error between Typhoon HIL and Matpower for each of the four cases

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | Vmag | Vmag | Vmag | Vmag |  | Vphase | Vphase | Vphase | Vphase |
| 1 | 0.000% | 0.000% | 0.000% | 0.000% |  | - | - | - | - |
| 2 | ***0.062%*** | 0.059% | ***0.064%*** | 0.060% |  | 475.652% | ***554.737%*** | 492.727% | ***580.000%*** |
| 3 | ***0.040%*** | 0.037% | ***0.042%*** | 0.038% |  | ***4220.000%*** | 2060.000% | ***3356.000%*** | 1820.000% |
| 4 | 0.916% | ***1.018%*** | 0.914% | ***1.017%*** |  | ***2.775%*** | 2.761% | ***2.771%*** | 2.758% |
| 5 | ***0.023%*** | 0.020% | ***0.025%*** | 0.021% |  | ***0.279%*** | 0.266% | ***0.273%*** | 0.263% |
| 6 | 0.023% | ***0.025%*** | 0.021% | ***0.024%*** |  | ***0.378%*** | 0.365% | ***0.372%*** | 0.362% |
| 7 | ***0.049%*** | 0.046% | ***0.051%*** | 0.047% |  | ***151.650%*** | 104.094% | ***144.528%*** | 99.385% |
| 8 | ***0.036%*** | 0.034% | ***0.038%*** | 0.034% |  | ***146.857%*** | 102.500% | ***140.000%*** | 96.364% |
| 9 | 0.804% | ***0.806%*** | 0.802% | ***0.805%*** |  | ***2.540%*** | 2.459% | ***2.530%*** | 2.449% |
| 10 | ***0.128%*** | 0.023% | ***0.130%*** | 0.024% |  | ***93.433%*** | 58.049% | ***89.197%*** | 55.210% |
| 11 | ***0.675%*** | 0.672% | ***0.677%*** | 0.673% |  | 1.199% | ***1.293%*** | 1.212% | ***1.305%*** |
| 12 | ***0.323%*** | 0.321% | ***0.325%*** | 0.322% |  | 0.106% | ***0.154%*** | 0.112% | ***0.160%*** |
| 13 | ***0.447%*** | 0.444% | ***0.449%*** | 0.445% |  | ***0.407%*** | ***0.456%*** | 0.275% | ***0.461%*** |
| 14 | ***0.685%*** | 0.683% | ***0.687%*** | 0.684% |  | 1.234% | ***1.327%*** | 1.246% | ***1.339%*** |
| 15 | ***0.018%*** | 0.011% | ***0.024%*** | 0.013% |  | - | - | - | - |
| 16 | 0.003% | ***0.020%*** | ***0.023%*** | 0.012% |  | ***36.604%*** | 18.233% | ***45.143%*** | 17.714% |
| 17 | 0.003% | 0.004% | ***0.009%*** | 0.002% |  | 183.077% | ***186.400%*** | 183.883% | ***188.163%*** |
| 18 | ***0.030%*** | 0.023% | ***0.036%*** | 0.025% |  | ***0.478%*** | 0.461% | ***0.471%*** | 0.458% |
| 19 | 0.031% | 0.038% | ***0.083%*** | 0.035% |  | ***0.478%*** | 0.465% | ***0.475%*** | 0.458% |

Table 6 – Active and reactive power error between Typhoon HIL and Matpower for each of the four cases

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | P | P | P | P |  | Q | Q | Q | Q |
| 1 | ***1.725%*** | ***1.718%*** | 0.143% | 0.139% |  | ***8.806%*** | 0.317% | ***11.123%*** | 0.377% |
|  |  |  |  |  |  |  |  |  |  |
| 16 | ***0.027%*** | 0.007% | ***0.027%*** | 0.013% |  | ***6.184%*** | ***2.764%*** | 1.082% | 0.982% |

Table 7 - Typhoon HIL voltage magnitude, phase angle, active and reactive power for DG in PV mode (single case)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 |  | Case 1 |  | Case 1 |  | Case 1 |
| # | Vmag |  | Vphase |  | P |  | Q |
| 1 | 1.000 |  | 0.000 |  | 2.595 |  | 2.789 |
| 2 | 0.999 |  | -0.086 |  |  |  |  |
| 3 | 0.996 |  | -0.173 |  |  |  |  |
| 4 | 0.984 |  | -31.023 |  |  |  |  |
| 5 | 0.985 |  | -30.936 |  |  |  |  |
| 6 | 0.952 |  | -31.368 |  |  |  |  |
| 7 | 0.985 |  | -0.259 |  |  |  |  |
| 8 | 0.985 |  | -0.259 |  |  |  |  |
| 9 | 0.975 |  | -31.023 |  |  |  |  |
| 10 | 0.982 |  | -0.259 |  |  |  |  |
| 11 | 0.971 |  | -31.368 |  |  |  |  |
| 12 | 0.954 |  | -62.736 |  |  |  |  |
| 13 | 0.958 |  | -62.391 |  |  |  |  |
| 14 | 0.970 |  | -31.368 |  |  |  |  |
| 15 | 0.999 |  | 0.000 |  |  |  |  |
| 16 | 1.000 |  | 0.173 |  | 1.500 |  | -1.008 |
| 17 | 0.999 |  | -0.086 |  |  |  |  |
| 18 | 0.998 |  | -30.072 |  |  |  |  |
| 19 | 0.933 |  | -30.850 |  |  |  |  |

Table 8 - Voltage magnitude and phase angle error between Typhoon HIL single case (PV mode) and the four Matpower cases

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | Vmag | Vmag | Vmag | Vmag |  | Vphase | Vphase | Vphase | Vphase |
| 1 | 0.000% | 0.000% | 0.000% | 0.000% |  | - | - | - | - |
| 2 | 0.063% | 0.063% | 0.063% | 0.063% |  | 475.652% | ***554.737%*** | 492.727% | ***580.000%*** |
| 3 | 0.040% | 0.040% | 0.040% | 0.040% |  | ***4220.000%*** | 2060.000% | ***3356.000%*** | 1820.000% |
| 4 | 0.898% | ***0.998%*** | 0.898% | ***0.998%*** |  | ***2.775%*** | 2.761% | ***2.771%*** | 2.758% |
| 5 | 0.023% | 0.023% | 0.023% | 0.023% |  | ***0.279%*** | 0.266% | ***0.273%*** | 0.263% |
| 6 | 0.022% | 0.022% | 0.022% | 0.022% |  | ***0.378%*** | 0.365% | ***0.372%*** | 0.362% |
| 7 | 0.050% | 0.050% | 0.050% | 0.050% |  | ***151.650%*** | 104.094% | ***144.528%*** | 99.385% |
| 8 | 0.037% | 0.037% | 0.037% | 0.037% |  | ***146.857%*** | 102.500% | ***140.000%*** | 96.364% |
| 9 | 0.804% | 0.804% | 0.804% | 0.804% |  | ***2.540%*** | 2.459% | ***2.530%*** | 2.449% |
| 10 | ***0.129%*** | 0.027% | ***0.129%*** | 0.027% |  | ***93.433%*** | 58.049% | ***89.197%*** | 55.210% |
| 11 | 0.676% | 0.676% | 0.676% | 0.676% |  | 1.199% | ***1.293%*** | 1.212% | ***1.305%*** |
| 12 | 0.324% | 0.324% | 0.324% | 0.324% |  | 0.106% | ***0.154%*** | 0.112% | ***0.160%*** |
| 13 | 0.448% | 0.448% | 0.448% | 0.448% |  | 0.269% | ***0.318%*** | 0.275% | ***0.323%*** |
| 14 | 0.686% | 0.686% | 0.686% | 0.686% |  | 1.234% | ***1.327%*** | 1.246% | ***1.339%*** |
| 15 | 0.020% | 0.020% | 0.020% | 0.020% |  | - | - | - | - |
| 16 | 0.011% | 0.011% | 0.011% | 0.011% |  | ***45.660%*** | ***45.489%*** | 45.143% | 45.143% |
| 17 | 0.005% | 0.005% | 0.005% | 0.005% |  | 183.090% | ***186.414%*** | 183.897% | ***188.178%*** |
| 18 | 0.031% | 0.031% | 0.031% | 0.031% |  | ***0.478%*** | 0.461% | ***0.471%*** | 0.458% |
| 19 | 0.029% | 0.029% | ***0.078%*** | 0.029% |  | ***0.478%*** | 0.465% | ***0.475%*** | 0.458% |

Table 9 – Active and Reactive power error between Ttphoon HIL single case (PV mode) and the four Matpower cases

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 |  | Case 1 | Case 2 | Case 3 | Case 4 |
| # | P | P | P | P |  | Q | Q | Q | Q |
| 1 | ***1.776%*** | ***1.776%*** | 0.205% | 0.205% |  | ***9.754%*** | 3.841% | ***9.461%*** | 3.509% |
|  |  |  |  |  |  |  |  |  |  |
| 16 | 0.027% | 0.027% | 0.027% | 0.027% |  | 2.898% | ***8.327%*** | 3.959% | ***7.486%*** |

For a final analysis, eight new cases were defined. In Matpower we used the most complete implementation (previous case 4) and changed the active power reference from zero to 3.5MVA with steps of 0.5MVA. In Typhoon HIL the schematic remains the same, the Diesel Genset operates in PV mode and follows the same active power reference as in Matpower. The cases are:

* Case 1 – Active power equals 0.0MVA
* Case 2 – Active power equals 0.5MVA
* Case 3 – Active power equals 1.0MVA
* Case 4 – Active power equals 1.5MVA
* Case 5 – Active power equals 2.0MVA
* Case 6 – Active power equals 2.5MVA
* Case 7 – Active power equals 3.0MVA
* Case 8 – Active power equals 3.5MVA

The tables below show part of the results.

Table 10 - Voltage magnitude comparison between each of the 8 cases in Matpower

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 |
| 3 | 0.996 | 0.996 | 0.996 | 0.996 | 0.996 | 0.996 | 0.996 | 0.996 |
| 4 | 0.993 | 0.994 | 0.994 | 0.994 | 0.993 | 0.993 | 0.993 | 0.993 |
| 5 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 |
| 6 | 0.951 | 0.952 | 0.952 | 0.952 | 0.952 | 0.952 | 0.952 | 0.952 |
| 7 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 |
| 8 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 | 0.985 |
| 9 | 0.983 | 0.983 | 0.983 | 0.983 | 0.983 | 0.983 | 0.983 | 0.983 |
| 10 | 0.981 | 0.982 | 0.982 | 0.982 | 0.982 | 0.982 | 0.982 | 0.982 |
| 11 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 |
| 12 | 0.951 | 0.951 | 0.951 | 0.951 | 0.951 | 0.951 | 0.951 | 0.951 |
| 13 | 0.954 | 0.954 | 0.954 | 0.954 | 0.954 | 0.954 | 0.954 | 0.954 |
| 14 | 0.963 | 0.963 | 0.963 | 0.963 | 0.963 | 0.963 | 0.963 | 0.963 |
| 15 | 0.998 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 |
| 16 | 0.998 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | 0.998 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 | 0.999 |
| 18 | 0.997 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 | 0.998 |
| 19 | 0.932 | 0.933 | 0.933 | 0.933 | 0.933 | 0.933 | 0.933 | 0.932 |

Table 11 - Voltage phase angle comparison between each of the 8 cases in Matpower

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | -0.026 | -0.023 | -0.002 | 0.018 | 0.039 | 0.059 | 0.08 | 0.1 |
| 3 | -0.053 | -0.05 | -0.029 | -0.009 | 0.012 | 0.032 | 0.053 | 0.073 |
| 4 | -30.234 | -30.231 | -30.211 | -30.19 | -30.169 | -30.149 | -30.129 | -30.108 |
| 5 | -30.9 | -30.897 | -30.876 | -30.855 | -30.835 | -30.814 | -30.794 | -30.774 |
| 6 | -31.3 | -31.297 | -31.276 | -31.255 | -31.235 | -31.214 | -31.194 | -31.174 |
| 7 | -0.174 | -0.171 | -0.151 | -0.13 | -0.109 | -0.089 | -0.069 | -0.048 |
| 8 | -0.176 | -0.173 | -0.152 | -0.132 | -0.111 | -0.09 | -0.07 | -0.05 |
| 9 | -30.325 | -30.322 | -30.302 | -30.281 | -30.26 | -30.24 | -30.219 | -30.199 |
| 10 | -0.211 | -0.208 | -0.187 | -0.167 | -0.146 | -0.126 | -0.105 | -0.085 |
| 11 | -31.827 | -31.824 | -31.803 | -31.783 | -31.762 | -31.741 | -31.721 | -31.701 |
| 12 | -62.881 | -62.878 | -62.857 | -62.837 | -62.816 | -62.796 | -62.775 | -62.755 |
| 13 | -62.638 | -62.635 | -62.614 | -62.593 | -62.573 | -62.552 | -62.532 | -62.512 |
| 14 | -31.838 | -31.835 | -31.814 | -31.794 | -31.773 | -31.753 | -31.732 | -31.712 |
| 15 | -0.035 | -0.026 | 0.037 | 0.099 | 0.161 | 0.223 | 0.284 | 0.345 |
| 16 | -0.045 | -0.021 | 0.147 | 0.315 | 0.482 | 0.649 | 0.815 | 0.98 |
| 17 | -0.036 | -0.027 | 0.036 | 0.098 | 0.16 | 0.221 | 0.283 | 0.344 |
| 18 | -30.069 | -30.06 | -29.997 | -29.935 | -29.873 | -29.812 | -29.75 | -29.689 |
| 19 | -30.843 | -30.834 | -30.771 | -30.709 | -30.647 | -30.586 | -30.524 | -30.463 |

Table 12 - Active power comparison between each of the 8 cases in Matpower

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | P | P | P | P | P | P | P | P |
| 1 | 4.08 | 3.58 | 3.09 | 2.59 | 2.1 | 1.61 | 1.13 | 0.65 |
|  |  |  |  |  |  |  |  |  |
| 16 | 0 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 |

Table 13 - Reactive power comparison between each of the 8 cases in Matpower

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Q | Q | Q | Q | Q | Q | Q | Q |
| 1 | 1.8 | 1.57 | 2.23 | 2.89 | 3.55 | 4.21 | 4.87 | 5.53 |
|  |  |  |  |  |  |  |  |  |
| 16 | 0 | 0.22 | -0.43 | -1.09 | -1.74 | -2.39 | -3.04 | -3.68 |

Table 14 - Voltage magnitude comparison between each of the 8 cases in Typhoon HIL

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 0.99837 | 0.998581 | 0.998605 | 0.998625 | 0.998651 | 0.998672 | 0.998693 | 0.998713 |
| 3 | 0.99615 | 0.996359 | 0.996383 | 0.996403 | 0.996428 | 0.99645 | 0.99647 | 0.99649 |
| 4 | 0.983661 | 0.983875 | 0.983896 | 0.984083 | 0.983938 | 0.983958 | 0.983979 | 0.983999 |
| 5 | 0.984981 | 0.985188 | 0.985208 | 0.985229 | 0.98525 | 0.985271 | 0.985292 | 0.985319 |
| 6 | 0.951549 | 0.95175 | 0.951771 | 0.951792 | 0.951813 | 0.951833 | 0.951854 | 0.951876 |
| 7 | 0.985155 | 0.985444 | 0.985468 | 0.985488 | 0.985513 | 0.985534 | 0.985555 | 0.985574 |
| 8 | 0.985029 | 0.985318 | 0.985342 | 0.985362 | 0.985387 | 0.985409 | 0.985429 | 0.985449 |
| 9 | 0.974775 | 0.975048 | 0.975096 | 0.975096 | 0.975144 | 0.975144 | 0.975192 | 0.975193 |
| 10 | 0.981907 | 0.982218 | 0.982242 | 0.982262 | 0.982286 | 0.982308 | 0.982328 | 0.982348 |
| 11 | 0.970008 | 0.970469 | 0.970493 | 0.970512 | 0.970536 | 0.970558 | 0.970579 | 0.970598 |
| 12 | 0.953573 | 0.954042 | 0.954063 | 0.954083 | 0.954104 | 0.954125 | 0.954146 | 0.954167 |
| 13 | 0.957662 | 0.958229 | 0.95825 | 0.958271 | 0.958292 | 0.958313 | 0.958333 | 0.958354 |
| 14 | 0.969102 | 0.969563 | 0.969587 | 0.969606 | 0.96963 | 0.969651 | 0.969673 | 0.969692 |
| 15 | 0.998415 | 0.999025 | 0.99912 | 0.999202 | 0.999301 | 0.99939 | 0.999475 | 0.999559 |
| 16 | 0.998433 | 1.000133 | 1.000134 | 1.000105 | 1.000132 | 1.000133 | 1.000135 | 1.000134 |
| 17 | 0.998264 | 0.998874 | 0.998968 | 0.999051 | 0.99915 | 0.999238 | 0.999325 | 0.999408 |
| 18 | 0.99753 | 0.998146 | 0.998229 | 0.998313 | 0.998417 | 0.9985 | 0.998604 | 0.99868 |
| 19 | 0.931996 | 0.932563 | 0.932667 | 0.932729 | 0.932833 | 0.932917 | 0.933 | 0.93307 |

Table 15 - Voltage phase angle comparison between each of the 8 cases in Typhoon HIL

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase |
| 1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | -0.086 | -0.086 | -0.086 | -0.086 | -0.086 | 0.000 | 0.000 | 0.000 |
| 3 | -0.173 | -0.173 | -0.173 | -0.173 | -0.173 | -0.086 | -0.086 | -0.086 |
| 4 | -31.023 | -31.023 | -30.760 | -31.023 | -31.023 | -30.936 | -30.936 | -30.936 |
| 5 | -31.023 | -31.023 | -30.680 | -30.936 | -30.936 | -30.936 | -30.936 | -30.850 |
| 6 | -31.368 | -31.368 | -31.110 | -31.368 | -31.368 | -31.282 | -31.282 | -31.282 |
| 7 | -0.259 | -0.259 | -0.259 | -0.259 | -0.259 | -0.259 | -0.173 | -0.173 |
| 8 | -0.259 | -0.259 | -0.259 | -0.259 | -0.259 | -0.259 | -0.173 | -0.173 |
| 9 | -31.023 | -31.368 | -30.763 | -31.023 | -30.936 | -30.936 | -30.936 | -30.936 |
| 10 | -0.346 | -0.346 | -0.346 | -0.259 | -0.259 | -0.259 | -0.259 | -0.173 |
| 11 | -31.455 | -31.368 | -31.109 | -31.368 | -31.368 | -31.368 | -31.282 | -31.282 |
| 12 | -62.736 | -62.736 | -62.045 | -62.736 | -62.736 | -62.736 | -62.650 | -62.650 |
| 13 | -62.391 | -62.391 | -61.790 | -62.391 | -62.304 | -62.304 | -62.300 | -62.304 |
| 14 | -31.455 | -31.455 | -31.109 | -31.368 | -31.368 | -31.368 | -31.280 | -31.282 |
| 15 | -0.086 | -0.086 | 0.000 | 0.000 | 0.086 | 0.086 | 0.173 | 0.259 |
| 16 | -0.173 | -0.086 | 0.086 | 0.173 | 0.346 | 0.519 | 0.691 | 0.864 |
| 17 | -0.173 | -0.173 | -0.086 | -0.086 | 0.000 | 0.000 | 0.086 | 0.173 |
| 18 | -30.245 | -30.245 | -30.160 | -30.072 | -30.072 | -29.986 | -29.990 | -29.899 |
| 19 | -30.936 | -30.936 | -30.850 | -30.850 | -30.763 | -30.763 | -30.680 | -30.591 |

Table 16 - Active power comparison between each of the 8 cases in Typhoon HIL

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | P | P | P | P | P | P | P | P |
| 1 | 4.0903 | 3.5878 | 3.0923 | 2.5953 | 2.1001 | 1.6101 | 1.1212 | 0.6387 |
|  |  |  |  |  |  |  |  |  |
| 16 | 0 | 0.5004 | 0.9998 | 1.5004 | 2.0001 | 2.5008 | 3.0002 | 3.5003 |

Table 17 - Reactive power comparison between each of the 8 cases in Typhoon HIL

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Q | Q | Q | Q | Q | Q | Q | Q |
| 1 | 1.81 | 1.6528 | 2.2173 | 2.7886 | 3.339 | 3.904 | 4.4611 | 5.0107 |
|  |  |  |  |  |  |  |  |  |
| 16 | 0 | 0.1196 | -0.4409 | -1.0084 | -1.5546 | -2.1093 | -2.6576 | -3.1937 |

Table 18 - Voltage magnitude errors between Typhoon HIL and Matpower for each of the 8 cases

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag | Vmag |
| 1 | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| 2 | 0.037% | 0.058% | 0.061% | ***0.063%*** | ***0.065%*** | ***0.067%*** | ***0.069%*** | ***0.071%*** |
| 3 | 0.015% | 0.036% | 0.038% | ***0.040%*** | ***0.043%*** | ***0.045%*** | ***0.047%*** | ***0.049%*** |
| 4 | 0.940% | ***1.019%*** | ***1.017%*** | ***0.998%*** | 0.913% | 0.911% | 0.908% | 0.906% |
| 5 | 0.002% | 0.019% | 0.021% | ***0.023%*** | ***0.025%*** | ***0.027%*** | ***0.030%*** | ***0.032%*** |
| 6 | ***0.058%*** | ***0.026%*** | 0.024% | 0.022% | 0.020% | 0.018% | 0.015% | 0.013% |
| 7 | 0.016% | 0.045% | ***0.048%*** | ***0.050%*** | ***0.052%*** | ***0.054%*** | ***0.056%*** | ***0.058%*** |
| 8 | 0.003% | 0.032% | ***0.035%*** | ***0.037%*** | ***0.039%*** | ***0.041%*** | ***0.044%*** | ***0.046%*** |
| 9 | ***0.837%*** | ***0.809%*** | 0.804% | 0.804% | 0.799% | 0.799% | 0.794% | 0.794% |
| 10 | ***0.092%*** | 0.022% | 0.025% | 0.027% | 0.029% | 0.031% | 0.033% | 0.035% |
| 11 | 0.623% | 0.671% | ***0.674%*** | ***0.676%*** | ***0.678%*** | ***0.680%*** | ***0.683%*** | ***0.684%*** |
| 12 | 0.271% | ***0.320%*** | ***0.322%*** | ***0.324%*** | ***0.326%*** | ***0.329%*** | ***0.331%*** | ***0.333%*** |
| 13 | 0.384% | ***0.443%*** | ***0.445%*** | ***0.448%*** | ***0.450%*** | ***0.452%*** | ***0.454%*** | ***0.456%*** |
| 14 | 0.634% | 0.681% | ***0.684%*** | ***0.686%*** | ***0.688%*** | ***0.691%*** | ***0.693%*** | ***0.695%*** |
| 15 | ***0.042%*** | 0.002% | 0.012% | 0.020% | 0.030% | ***0.039%*** | ***0.048%*** | ***0.056%*** |
| 16 | ***0.043%*** | 0.013% | 0.013% | 0.011% | 0.013% | 0.013% | 0.013% | 0.013% |
| 17 | ***0.026%*** | 0.013% | 0.003% | 0.005% | 0.015% | ***0.024%*** | ***0.032%*** | ***0.041%*** |
| 18 | ***0.053%*** | 0.015% | 0.023% | 0.031% | 0.042% | ***0.050%*** | ***0.061%*** | ***0.068%*** |
| 19 | 0.000% | ***0.047%*** | ***0.036%*** | 0.029% | 0.018% | 0.009% | 0.000% | ***0.115%*** |

Table 19 - Voltage phase angle errors between Typhoon HIL and Matpower for each of the 8 cases

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase | Vphase |
| 1 | - | - | - | - | - | - | - | - |
| 2 | 232.308% | 275.652% | ***4220.000%*** | 580.000% | 321.538% | - | - | - |
| 3 | 226.038% | 245.656% | 495.862% | ***1820.000%*** | ***1540.000%*** | 370.000% | 263.019% | 218.356% |
| 4 | ***2.608%*** | ***2.619%*** | 1.817% | ***2.758%*** | ***2.829%*** | ***2.611%*** | ***2.679%*** | ***2.750%*** |
| 5 | ***0.397%*** | ***0.407%*** | ***0.635%*** | 0.263% | 0.328% | ***0.396%*** | ***0.461%*** | 0.246% |
| 6 | 0.218% | 0.227% | ***0.531%*** | ***0.362%*** | ***0.426%*** | 0.217% | 0.281% | ***0.346%*** |
| 7 | 48.966% | 51.579% | 71.656% | 99.385% | ***137.798%*** | ***191.236%*** | ***150.435%*** | ***260.000%*** |
| 8 | 47.273% | 49.827% | 70.526% | 96.364% | ***133.514%*** | ***188.000%*** | ***146.857%*** | ***245.600%*** |
| 9 | 2.300% | ***3.450%*** | 1.522% | ***2.449%*** | 2.234% | 2.302% | 2.373% | ***2.441%*** |
| 10 | 63.839% | 66.202% | 84.866% | 55.210% | 77.534% | ***105.714%*** | ***146.857%*** | ***103.294%*** |
| 11 | 1.170% | ***1.432%*** | ***2.182%*** | 1.305% | 1.240% | 1.175% | 1.385% | 1.322% |
| 12 | 0.230% | 0.225% | ***1.292%*** | 0.160% | 0.127% | 0.095% | 0.199% | 0.167% |
| 13 | 0.395% | 0.390% | ***1.316%*** | 0.323% | 0.429% | 0.396% | 0.371% | 0.332% |
| 14 | 1.204% | 1.195% | ***2.216%*** | 1.339% | 1.274% | 1.212% | ***1.424%*** | 1.357% |
| 15 | ***146.857%*** | ***232.308%*** | - | - | 46.335% | 61.256% | - | - |
| 16 | ***284.000%*** | ***311.429%*** | 41.224% | 45.143% | 28.278% | 20.108% | 15.178% | 11.827% |
| 17 | ***380.000%*** | ***540.000%*** | ***340.000%*** | 188.178% | - | - | 69.470% | 49.767% |
| 18 | 0.585% | 0.615% | 0.543% | 0.458% | ***0.666%*** | 0.582% | ***0.807%*** | ***0.708%*** |
| 19 | 0.302% | 0.331% | 0.257% | ***0.458%*** | 0.379% | ***0.580%*** | ***0.511%*** | ***0.419%*** |

Table 20 - Active power error between Typhoon HIL and Matpower for each of the 8 cases

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | P | P | P | P | P | P | P | P |
| 1 | 0.252% | 0.218% | 0.074% | 0.205% | 0.005% | 0.006% | ***0.779%*** | ***1.738%*** |
|  |  |  |  |  |  |  |  |  |
| 16 | - | ***0.080%*** | 0.020% | ***0.027%*** | 0.005% | ***0.032%*** | 0.007% | 0.009% |

Table 21 - Reactive power error between Typhoon HIL and Matpower for each of the 8 cases

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Bus | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 |
| # | Q | Q | Q | Q | Q | Q | Q | Q |
| 1 | 0.556% | ***5.274%*** | 0.570% | 3.509% | ***5.944%*** | ***7.268%*** | ***8.396%*** | ***9.391%*** |
|  |  |  |  |  |  |  |  |  |
| 16 | - | ***45.636%*** | 2.535% | 7.486% | 10.655% | 11.745% | 12.579% | 13.215% |

For more details refer to excel file PowerFlow\_Comparison\_v2.xlsx.

# Attachments

**Calculating\_Ymatrix\_Feeder1.m**

f = 60; % Hz

sys\_w = 2\*pi\*f; % rad/s

ft2mi = 1.0/5280.0; %mi/ft

[alphax,alphay] = pol2cart(-120\*pi/180,1);

alpha = alphax+1j\*alphay;

R1\_cable11 = 0.2685; % ohms/mi

X1\_cable11 = 0.207; % ohms/mi

R0\_cable11 = 2.1408; % ohms/mi

X0\_cable11 = 1.582; % ohms/mi

B\_cable11 = 308.7587e-6; % S/mi

L0\_cable11 = X0\_cable11/sys\_w; % H/mi

L1\_cable11 = X1\_cable11/sys\_w; % H/mi

C0\_cable11 = B\_cable11/sys\_w; % F/mi

R1\_cable13 = 0.1206; % ohms/mi

X1\_cable13 = 0.1878; % ohms/mi

R0\_cable13 = 1.8354; % ohms/mi

X0\_cable13 = 1.2165; % ohms/mi

B\_cable13 = 384.0177e-6; % S/mi

L0\_cable13 = X0\_cable13/sys\_w; % H/mi

L1\_cable13 = X1\_cable13/sys\_w; % H/mi

C0\_cable13 = B\_cable13/sys\_w; % F/mi

% # Utility

l\_U\_L2 = 500.0\*ft2mi; % mi

% # Feeder1

l\_F1L1 = 1800.0\*ft2mi; % mi

l\_F1L2 = 5500.0\*ft2mi; % mi

l\_F1L3 = 1000.0\*ft2mi; % mi

l\_F1L4 = 3000.0\*ft2mi; % mi

l\_F1L5 = 3000.0\*ft2mi; % mi

l\_F1L6 = 1500.0\*ft2mi; % mi

l\_F1L7 = 2000.0\*ft2mi; % mi

l\_F1L8 = 1000.0\*ft2mi; % mi

l\_F1L9 = 2000.0\*ft2mi; % mi

l\_F1DG = 2000.0\*ft2mi; % mi

A = [1,1,1; 1,alpha^2,alpha; 1,alpha,alpha^2];

Rabc11 = A\*diag([R0\_cable11;R1\_cable11;R1\_cable11])/A;

Xabc11 = A\*diag([X0\_cable11;X1\_cable11;X1\_cable11])/A;

Rabc13 = A\*diag([R0\_cable13;R1\_cable13;R1\_cable13])/A;

Xabc13 = A\*diag([X0\_cable13;X1\_cable13;X1\_cable13])/A;

Zabc11 = Rabc11+1j\*Xabc11;

Zabc13 = Rabc13+1j\*Xabc13;

Z11 = Zabc11(1,1)

Z13 = Zabc13(1,1)

Z1to2 = l\_U\_L2\*Z13;

Z2to3 = l\_F1L1\*Z13;

Z2to7 = l\_F1L2\*Z13;

Z2to15 = l\_F1L3\*Z13;

Z15to17 = l\_F1L4\*Z13;

Z7to8 = l\_F1L5\*Z13;

Z7to10 = l\_F1L6\*Z13;

Z11to14 = l\_F1L7\*Z13;

Z5to6 = l\_F1L8\*Z13;

Z18to19 = l\_F1L9\*Z13;

Z15to16 = l\_F1DG\*Z11;

Zb1 = (13800^2)/3.75e6;

Zb2 = (480^2)/3.75e6;

Zb3 = (208^2)/3.75e6;

Zb4 = (4160^2)/3.75e6;

% ZlinesPU = zeros(19,19);

Z1to2PU = Z1to2/Zb1;

Z2to3PU = Z2to3/Zb1;

Z2to7PU = Z2to7/Zb1;

Z2to15PU = Z2to15/Zb1;

Z15to17PU = Z15to17/Zb1;

Z7to8PU = Z7to8/Zb1;

Z7to10PU = Z7to10/Zb1;

Z11to14PU = Z11to14/Zb4;

Z5to6PU = Z5to6/Zb2;

Z18to19PU = Z18to19/Zb2;

Z15to16PU = Z15to16/Zb1;

Sn\_500kVA\_1 = 500.0e3; % VA

V1\_500kVA\_1 = 13800.0; % V

V2\_500kVA\_1 = 480.0; % V

Z\_500kVA\_1 = 5.0/100.0; % pu

Z\_ratio\_500kVA\_1 = 4.9;

Rm\_500kVA\_1 = 1e5/3;

Lm\_500kVA\_1 = 200/3;

R\_500kVA\_1 = Z\_500kVA\_1/sqrt(1.0+Z\_ratio\_500kVA\_1^2.0); % pu

X\_500kVA\_1 = Z\_ratio\_500kVA\_1\*R\_500kVA\_1; % pu

G\_500kVA\_1 = 1/(Rm\_500kVA\_1/((V1\_500kVA\_1^2)/3.75e6));

B\_500kVA\_1 = 1/((sys\_w\*Lm\_500kVA\_1)/((V1\_500kVA\_1^2)/3.75e6));

Sn\_500kVA\_2 = 500.0e3; % VA

V1\_500kVA\_2 = 13800.0; % V

V2\_500kVA\_2 = 208.0; % V

Z\_500kVA\_2 = 5.0/100.0; % pu

Z\_ratio\_500kVA\_2 = 4.9;

Rm\_500kVA\_2 = 1e5/3;

Lm\_500kVA\_2 = 200/3;

R\_500kVA\_2 = Z\_500kVA\_2/sqrt(1.0+Z\_ratio\_500kVA\_2^2.0); % pu

X\_500kVA\_2 = Z\_ratio\_500kVA\_2\*R\_500kVA\_2; % pu

G\_500kVA\_2 = 1/(Rm\_500kVA\_2/((V1\_500kVA\_2^2)/3.75e6));

B\_500kVA\_2 = 1/((sys\_w\*Lm\_500kVA\_2)/((V1\_500kVA\_2^2)/3.75e6));

Sn\_2MVA\_1 = 2000.0e3; % VA

V1\_2MVA\_1 = 4160.0; % V

V2\_2MVA\_1 = 480.0; % V

Z\_2MVA\_1 = 5.75/100.0; % pu

Z\_ratio\_2MVA\_1 = 5.7;

Rm\_2MVA\_1 = 1e5/3;

Lm\_2MVA\_1 = 200/3;

R\_2MVA\_1 = Z\_2MVA\_1/sqrt(1.0+Z\_ratio\_2MVA\_1^2.0); % pu

X\_2MVA\_1 = Z\_ratio\_2MVA\_1\*R\_2MVA\_1; % pu

G\_2MVA\_1 = 1/(Rm\_2MVA\_1/((V1\_2MVA\_1^2)/3.75e6));

B\_2MVA\_1 = 1/((sys\_w\*Lm\_2MVA\_1)/((V1\_2MVA\_1^2)/3.75e6));

Sn\_2500kVA\_1 = 2500.0e3; % VA

V1\_2500kVA\_1 = 13800.0; % V

V2\_2500kVA\_1 = 480.0; % V

Z\_2500kVA\_1 = 5.56/100.0; % pu

Z\_ratio\_2500kVA\_1 = 5.52;

Rm\_2500kVA\_1 = 1e5/3;

Lm\_2500kVA\_1 = 200/3;

R\_2500kVA\_1 = Z\_2500kVA\_1/sqrt(1.0+Z\_ratio\_2500kVA\_1^2.0); % pu

X\_2500kVA\_1 = Z\_ratio\_2500kVA\_1\*R\_2500kVA\_1; % pu

G\_2500kVA\_1 = 1/(Rm\_2500kVA\_1/((V1\_2500kVA\_1^2)/3.75e6));

B\_2500kVA\_1 = 1/((sys\_w\*Lm\_2500kVA\_1)/((V1\_2500kVA\_1^2)/3.75e6));

Sn\_2500kVA\_2 = 2500.0e3; % VA

V1\_2500kVA\_2 = 13800.0; % V

V2\_2500kVA\_2 = 480.0; % V

Z\_2500kVA\_2 = 5.75/100.0; % pu

Z\_ratio\_2500kVA\_2 = 6.6;

Rm\_2500kVA\_2 = 1e5/3;

Lm\_2500kVA\_2 = 200/3;

R\_2500kVA\_2 = Z\_2500kVA\_2/sqrt(1.0+Z\_ratio\_2500kVA\_2^2.0); %pu

X\_2500kVA\_2 = Z\_ratio\_2500kVA\_2\*R\_2500kVA\_2; % pu

G\_2500kVA\_2 = 1/(Rm\_2500kVA\_2/((V1\_2500kVA\_2^2)/3.75e6));

B\_2500kVA\_2 = 1/((sys\_w\*Lm\_2500kVA\_2)/((V1\_2500kVA\_2^2)/3.75e6));

Sn\_3750kVA = 3750.0e3; % VA

V1\_3750kVA = 13800.0; % V

V2\_3750kVA = 4160.0; % V

Z\_3750kVA = 4.75/100.0; % pu

Z\_ratio\_3750kVA = 11.4;

Rm\_3750kVA = 1e5/3; %division by 3 to change from delta to wye

Lm\_3750kVA = 200/3;

R\_3750kVA = Z\_3750kVA/sqrt(1.0+Z\_ratio\_3750kVA^2.0); % pu

X\_3750kVA = Z\_ratio\_3750kVA\*R\_3750kVA; % pu

G\_3750kVA = 1/(Rm\_3750kVA/((V1\_3750kVA^2)/3.75e6));

B\_3750kVA = 1/((sys\_w\*Lm\_3750kVA)/((V1\_3750kVA^2)/3.75e6));

Zt3to4PU = R\_500kVA\_1+1j\*X\_500kVA\_1;

Zt7to9PU = R\_500kVA\_2+1j\*X\_500kVA\_2;

Zt11to13PU = R\_2MVA\_1+1j\*X\_2MVA\_1;

Zt11to12PU = R\_2MVA\_1+1j\*X\_2MVA\_1;

Zt3to5PU = R\_2500kVA\_1+1j\*X\_2500kVA\_1;

Zt17to18PU = R\_2500kVA\_2+1j\*X\_2500kVA\_2;

Zt10to11PU = R\_3750kVA+1j\*X\_3750kVA;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%% Create the branch impedance matrix %%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% The first column is the Bus from which the branch starts

% The second column is the Bus where the branch arrives

% The third column is the resistance of the branch [pu]

% The fourth column is the reactance of the branch [pu]

% The fifth column is the branch conductance [pu]

% The sixth column is the branch admitance [pu]

Branch = zeros(18,6);

Branch(1,:) = [1,2,real(Z1to2PU),imag(Z1to2PU),0,0];

Branch(2,:) = [2,3,real(Z2to3PU),imag(Z2to3PU),0,0];

Branch(3,:) = [2,7,real(Z2to7PU),imag(Z2to7PU),0,0];

Branch(4,:) = [2,15,real(Z2to15PU),imag(Z2to15PU),0,0];

Branch(5,:) = [3,4,real(Zt3to4PU),imag(Zt3to4PU),G\_500kVA\_1,B\_500kVA\_1];

Branch(6,:) = [3,5,real(Zt3to5PU),imag(Zt3to5PU),G\_2500kVA\_1,B\_2500kVA\_1];

Branch(7,:) = [5,6,real(Z5to6PU),imag(Z5to6PU),0,0];

Branch(8,:) = [7,8,real(Z7to8PU),imag(Z7to8PU),0,0];

Branch(9,:) = [7,9,real(Zt7to9PU),imag(Zt7to9PU),G\_500kVA\_2,B\_500kVA\_2];

Branch(10,:) = [7,10,real(Z7to10PU),imag(Z7to10PU),0,0];

Branch(11,:) = [10,11,real(Zt10to11PU),imag(Zt10to11PU),G\_3750kVA,B\_3750kVA];

Branch(12,:) = [11,12,real(Zt11to12PU),imag(Zt11to12PU),G\_2MVA\_1,B\_2MVA\_1];

Branch(13,:) = [11,13,real(Zt11to13PU),imag(Zt11to13PU),G\_2MVA\_1,B\_2MVA\_1];

Branch(14,:) = [11,14,real(Z11to14PU),imag(Z11to14PU),0,0];

Branch(15,:) = [15,16,real(Z15to16PU),imag(Z15to16PU),0,0];

Branch(16,:) = [15,17,real(Z15to17PU),imag(Z15to17PU),0,0];

Branch(17,:) = [17,18,real(Zt17to18PU),imag(Zt17to18PU),G\_2500kVA\_2,B\_2500kVA\_2];

Branch(18,:) = [18,19,real(Z18to19PU),imag(Z18to19PU),0,0];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%% Calculates Constant Impedance loads %%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% The column number one is the bus where the load is connected

% The column number two is the real power at that bus at rated voltage [MW]

% The column number three is the reactive power at that bus at rated

% voltage [MVAr]

Load = zeros(10,3);

Load(1,:) = [4,0.3\*0.9,0.3\*sin(acos(0.9))];

Load(2,:) = [5,1.2\*0.9,1.2\*sin(acos(0.9))];

Load(3,:) = [6,0.05\*0.9,0.05\*sin(acos(0.9))];

Load(4,:) = [8,0.05\*0.9,0.05\*sin(acos(0.9))];

Load(5,:) = [9,0.25\*0.9,0.25\*sin(acos(0.9))];

Load(6,:) = [12,1.5\*0.9,1.5\*sin(acos(0.9))];

Load(7,:) = [13,1.0\*0.9,1.0\*sin(acos(0.9))];

Load(8,:) = [13,0.149\*0.9,0.149\*sin(acos(0.9))];

Load(9,:) = [14,0.05\*0.9,0.05\*sin(acos(0.9))];

Load(10,:) = [19,0.05\*0.9,0.05\*sin(acos(0.9))];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%% Calculates Trafo shunt resistance losses %%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Column 1 is the bus where the resistance losses happen

% Column 2 is the power loss in the resistors at nominal voltage [MW]

Trafo\_sh\_loss = zeros(5,2);

Trafo\_sh\_loss(1,:) = [3,2\*5.7e3/1e6];

Trafo\_sh\_loss(2,:) = [7,5.7e3/1e6];

Trafo\_sh\_loss(3,:) = [10,5.7e3/1e6];

Trafo\_sh\_loss(4,:) = [11,2\*519/1e6];

Trafo\_sh\_loss(5,:) = [17,5.7e3/1e6];

**Feeder1BansheeSimple.m**

function mpc = Feeder1BansheeSimple

% Power Flow calculation of Feeder 1 from Banshee model. Transmission lines

% are considered simple RL loads, WITHOUT shunt capacitances and mutual

% coupling. Impedance from core coupling and snubbers ARE NOT considered.

%Shunt resistors for measurement units ARE NOT considered. Shunt losses of

% the transformers ARE considered (resistive and inductive).

%% MATPOWER Case Format : Version 2

mpc.version = '2';

%%----- Power Flow Data -----%%

%% system MVA base

mpc.baseMVA = 3.75;

%% bus data

% bus\_i type Pd Qd Gs Bs area Vm Va baseKV zone Vmax Vmin

mpc.bus = [

1 3 0 0 0.00 0.00 1 1 0 13.8 1 1.10 0.90;

2 1 0 0 0.00 0.00 1 1 0 13.8 1 1.10 0.90;

3 1 0 0 0.0114 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2)

4 1 0 0 0.27 -0.1308 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

5 1 0 0 1.08 -0.5231 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

6 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

7 1 0 0 0.0057 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo

8 1 0 0 0.045 -0.0218 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the power of the shunt load

9 1 0 0 0.225 -0.109 1 1 0 0.208 1 1.10 0.90; %Pd and Qd are the power of the shunt load

10 1 0 0 0.0057 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo

11 1 0 0 0.001 0.00 1 1 0 4.16 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2)

12 1 0 0 1.35 -0.6538 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

13 1 0 0 1.0341 -0.5008 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

14 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

15 1 0 0 0.04 0.00 1 1 0 13.8 1 1.10 0.90;

16 2 0 0 0.04 0.00 1 1 0 13.8 1 1.10 0.90;

17 1 0 0 0.0057 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo

18 1 0 0 0.00 0.00 1 1 0 0.48 1 1.10 0.90;

19 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

];

%% generator data

% bus Pg Qg Qmax Qmin Vg mBase status Pmax Pmin Pc1 Pc2 Qc1min Qc1max Qc2min Qc2max ramp\_agc ramp\_10 ramp\_30 ramp\_q apf

mpc.gen = [

1 0 0 30 -30 1 100 1 100 0 0 0 0 0 0 0 0 0 0 0 0;

16 1.5 0 2.0 -2.0 1 4 1 4 0 0 0 0 0 0 0 0 0 0 0 0;

];

%% branch data

% fbus tbus r x b rateA rateB rateC ratio angle status angmin angmax

mpc.branch = [

1 2 0.0013 9.9e-4 0.00 0 0 0 0 0 1 -360 360;

2 3 0.0046 0.0036 0.00 0 0 0 0 0 1 -360 360;

2 7 0.0142 0.0109 0.00 0 0 0 0 0 1 -360 360;

2 15 0.0026 0.002 0.00 0 0 0 0 0 1 -360 360;

3 4 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

3 5 0.0099 0.0547 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

5 6 2.1338 1.6359 0.00 0 0 0 0 0 1 -360 360;

7 8 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

7 9 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

7 10 0.0039 0.003 0.00 0 0 0 0 0 1 -360 360;

10 11 0.0042 0.0473 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 12 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 13 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 14 0.0568 0.0436 0.00 0 0 0 0 0 1 -360 360;

15 16 0.0067 0.005 0.00 0 0 0 0 0 1 -360 360;

15 17 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

17 18 0.0086 0.0569 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

18 19 4.2675 3.2719 0.00 0 0 0 0 0 1 -360 360;

];

%%----- OPF Data -----%%

%% generator cost data

% 1 startup shutdown n x1 y1 ... xn yn

% 2 startup shutdown n c(n-1) ... c0

mpc.gencost = [

1 0 0 1 0;

1 0 0 1 0;

];

**Feeder1Banshee.m**

function mpc = Feeder1Banshee

% Power Flow calculation of Feeder 1 from Banshee model. Transmission lines

% are considered simple RL loads, WITHOUT shunt capacitances and mutual

% coupling. Impedance from core coupling and snubbers ARE considered. Shunt

% resistors for measurements ARE NOT considered. Shunt losses of the

% transformers ARE considered (resistive and inductive).

%% MATPOWER Case Format : Version 2

mpc.version = '2';

%%----- Power Flow Data -----%%

%% system MVA base

mpc.baseMVA = 3.75;

%% bus data

% bus\_i type Pd Qd Gs Bs area Vm Va baseKV zone Vmax Vmin

mpc.bus = [

1 3 0 0 0.00 0.00 1 1 0 13.8 1 1.10 0.90;

2 1 0 0 2.7e-4 0.0718 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the shunt loss of the Coupling

3 1 0 0 0.0114 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2)

4 1 0 0 0.27 -0.1308 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

5 1 0 0 1.08 -0.5231 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

6 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

7 1 0 0 0.0057 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo

8 1 0 0 0.045 -0.0218 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the power of the shunt load

9 1 0 0 0.225 -0.109 1 1 0 0.208 1 1.10 0.90; %Pd and Qd are the power of the shunt load

10 1 0 0 0.0060 0.0897 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the sum of the shunt loss of Trafo and Coupling

11 1 0 0 0.001 0.00 1 1 0 4.16 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2)

12 1 0 0 1.35 -0.6538 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

13 1 0 0 1.03412 -0.4965 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the sum of the shunt loss of Trafo and Coupling

14 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

15 1 0 0 0.04027 0.0718 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the shunt loss of the Coupling

16 2 0 0 0.04027 0.0717 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the shunt loss of the Genset Snubbers and Dummy load

17 1 0 0 0.0057 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo

18 1 0 0 0.00 0.00 1 1 0 0.48 1 1.10 0.90;

19 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

];

%% generator data

% bus Pg Qg Qmax Qmin Vg mBase status Pmax Pmin Pc1 Pc2 Qc1min Qc1max Qc2min Qc2max ramp\_agc ramp\_10 ramp\_30 ramp\_q apf

mpc.gen = [

1 0 0 30 -30 1 100 1 100 0 0 0 0 0 0 0 0 0 0 0 0;

16 1.5 0 2.0 -2.0 1 4 1 4 0 0 0 0 0 0 0 0 0 0 0 0;

];

%% branch data

% fbus tbus r x b rateA rateB rateC ratio angle status angmin angmax

mpc.branch = [

1 2 0.0013 9.9e-4 0.00 0 0 0 0 0 1 -360 360;

2 3 0.0046 0.0036 0.00 0 0 0 0 0 1 -360 360;

2 7 0.0142 0.0109 0.00 0 0 0 0 0 1 -360 360;

2 15 0.0026 0.002 0.00 0 0 0 0 0 1 -360 360;

3 4 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

3 5 0.0099 0.0547 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

5 6 2.1338 1.6359 0.00 0 0 0 0 0 1 -360 360;

7 8 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

7 9 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

7 10 0.0039 0.003 0.00 0 0 0 0 0 1 -360 360;

10 11 0.0042 0.0473 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 12 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 13 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 14 0.0568 0.0436 0.00 0 0 0 0 0 1 -360 360;

15 16 0.0067 0.005 0.00 0 0 0 0 0 1 -360 360;

15 17 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

17 18 0.0086 0.0569 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

18 19 4.2675 3.2719 0.00 0 0 0 0 0 1 -360 360;

];

%%----- OPF Data -----%%

%% generator cost data

% 1 startup shutdown n x1 y1 ... xn yn

% 2 startup shutdown n c(n-1) ... c0

mpc.gencost = [

1 0 0 1 0;

1 0 0 1 0;

];

**Feeder1BansheeNosnubbers.m**

function mpc = Feeder1BansheeNosnubbers

% Power Flow calculation of Feeder 1 from Banshee model. Transmission lines

% are considered simple RL loads, without shunt capacitances and mutual

% coupling. Impedance from core coupling and snubbers ARE NOT considered. Shunt

% resistors for measurements ARE considered. Shunt losses of the

% transformers ARE considered (resistive and inductive).

%% MATPOWER Case Format : Version 2

mpc.version = '2';

%%----- Power Flow Data -----%%

%% system MVA base

mpc.baseMVA = 3.75;

%% bus data

% bus\_i type Pd Qd Gs Bs area Vm Va baseKV zone Vmax Vmin

mpc.bus = [

1 3 0 0 0.00 0.00 1 1 0 13.8 1 1.10 0.90;

2 1 0 0 0.0152 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the shunt loss of the Measurements

3 1 0 0 0.0190 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2) and the Measurements

4 1 0 0 0.27 -0.1308 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

5 1 0 0 1.08 -0.5231 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

6 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

7 1 0 0 0.0171 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo and the Measurements

8 1 0 0 0.045 -0.0218 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the power of the shunt load

9 1 0 0 0.225 -0.109 1 1 0 0.208 1 1.10 0.90; %Pd and Qd are the power of the shunt load

10 1 0 0 0.0076 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the sum of the shunt loss of Trafo and Measurements

11 1 0 0 0.0017 0.00 1 1 0 4.16 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2) and the Measurements

12 1 0 0 1.35 -0.6538 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

13 1 0 0 1.0341 -0.5008 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

14 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

15 1 0 0 0.04381 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the shunt loss of the Measurements

16 2 0 0 0.04 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the shunt loss of the Genset Measurements and Dummy load

17 1 0 0 0.0095 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo and the Measurements

18 1 0 0 4.6e-6 0.00 1 1 0 0.48 1 1.10 0.90; %Pd is the shunt loss of the Measurements

19 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

];

%% generator data

% bus Pg Qg Qmax Qmin Vg mBase status Pmax Pmin Pc1 Pc2 Qc1min Qc1max Qc2min Qc2max ramp\_agc ramp\_10 ramp\_30 ramp\_q apf

mpc.gen = [

1 0 0 30 -30 1 100 1 100 0 0 0 0 0 0 0 0 0 0 0 0;

16 1.5 0 2.0 -2.0 1 4 1 4 0 0 0 0 0 0 0 0 0 0 0 0;

% 16 1.5 0 2.0 -2.0 1 4 1 4 0 0 0 0 0 0 0 0 0 0 0 0;

];

%% branch data

% fbus tbus r x b rateA rateB rateC ratio angle status angmin angmax

mpc.branch = [

1 2 0.0013 9.9e-4 0.00 0 0 0 0 0 1 -360 360;

2 3 0.0046 0.0036 0.00 0 0 0 0 0 1 -360 360;

2 7 0.0142 0.0109 0.00 0 0 0 0 0 1 -360 360;

2 15 0.0026 0.002 0.00 0 0 0 0 0 1 -360 360;

3 4 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

3 5 0.0099 0.0547 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

5 6 2.1338 1.6359 0.00 0 0 0 0 0 1 -360 360;

7 8 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

7 9 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

7 10 0.0039 0.003 0.00 0 0 0 0 0 1 -360 360;

10 11 0.0042 0.0473 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 12 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 13 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 14 0.0568 0.0436 0.00 0 0 0 0 0 1 -360 360;

15 16 0.0067 0.005 0.00 0 0 0 0 0 1 -360 360;

15 17 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

17 18 0.0086 0.0569 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

18 19 4.2675 3.2719 0.00 0 0 0 0 0 1 -360 360;

];

%%----- OPF Data -----%%

%% generator cost data

% 1 startup shutdown n x1 y1 ... xn yn

% 2 startup shutdown n c(n-1) ... c0

mpc.gencost = [

1 0 0 1 0;

1 0 0 1 0;

];

**Feeder1BansheeFULL.m**

function mpc = Feeder1BansheeFULL

% Power Flow calculation of Feeder 1 from Banshee model. Transmission lines

% are considered simple RL loads, WITHOUT shunt capacitances and mutual

% coupling. Impedance from core coupling and snubbers ARE considered. Shunt

% resistors for measurements ARE considered. Shunt losses of the

% transformers ARE considered (resistive and inductive).

%% MATPOWER Case Format : Version 2

mpc.version = '2';

%%----- Power Flow Data -----%%

%% system MVA base

mpc.baseMVA = 3.75;

%% bus data

% bus\_i type Pd Qd Gs Bs area Vm Va baseKV zone Vmax Vmin

mpc.bus = [

1 3 0 0 0.00 0.00 1 1 0 13.8 1 1.10 0.90;

2 1 0 0 0.0155 0.0718 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the shunt loss of the Coupling and the Measurements

3 1 0 0 0.0190 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2) and the Measurements

4 1 0 0 0.27 -0.1308 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

5 1 0 0 1.08 -0.5231 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

6 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

7 1 0 0 0.0171 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo and the Measurements

8 1 0 0 0.045 -0.0218 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the power of the shunt load

9 1 0 0 0.225 -0.109 1 1 0 0.208 1 1.10 0.90; %Pd and Qd are the power of the shunt load

10 1 0 0 0.00794 0.0897 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the sum of the shunt loss of Trafo, Coupling and Measurements

11 1 0 0 0.0017 0.00 1 1 0 4.16 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo (x2) and the Measurements

12 1 0 0 1.35 -0.6538 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

13 1 0 0 1.03412 -0.4965 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the sum of the shunt loss of Trafo and Coupling

14 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

15 1 0 0 0.0441 0.0718 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the shunt loss of the Coupling and the Measurements

16 2 0 0 0.04027 0.0717 1 1 0 13.8 1 1.10 0.90; %Pd and Qd are the shunt loss of the Genset Snubbers and Dummy load

17 1 0 0 0.0095 0.00 1 1 0 13.8 1 1.10 0.90; %Pd is the resistive shunt loss of the trafo and the Measurements

18 1 0 0 4.61e-6 0.00 1 1 0 0.48 1 1.10 0.90; %Pd is the shunt loss of the Measurements

19 1 0 0 0.045 -0.0218 1 1 0 0.48 1 1.10 0.90; %Pd and Qd are the power of the shunt load

];

%% generator data

% bus Pg Qg Qmax Qmin Vg mBase status Pmax Pmin Pc1 Pc2 Qc1min Qc1max Qc2min Qc2max ramp\_agc ramp\_10 ramp\_30 ramp\_q apf

mpc.gen = [

1 0.00 0.00 4.00 -4.00 1 4.5 1 4.5 0 0 0 0 0 0 0 0 0 0 0 0;

16 3.5 0 2.00 -2.00 1 3.5 1 3.5 0 0 0 0 0 0 0 0 0 0 0 0;

% 16 1.5 0 2.00 -2.00 1 3.5 1 3.5 0 0 0 0 0 0 0 0 0 0 0 0;

];

%% branch data

% fbus tbus r x b rateA rateB rateC ratio angle status angmin angmax

mpc.branch = [

1 2 0.0013 9.896e-4 0.00 0 0 0 0 0 1 -360 360;

2 3 0.0046 0.0036 0.00 0 0 0 0 0 1 -360 360;

2 7 0.0142 0.0109 0.00 0 0 0 0 0 1 -360 360;

2 15 0.0026 0.002 0.00 0 0 0 0 0 1 -360 360;

3 4 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

3 5 0.0099 0.0547 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

5 6 2.1338 1.6359 0.00 0 0 0 0 0 1 -360 360;

7 8 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

7 9 0.01 0.049 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

7 10 0.0039 0.003 0.00 0 0 0 0 0 1 -360 360;

10 11 0.0042 0.0473 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 12 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 13 0.0099 0.0566 -1.8362e-4 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

11 14 0.0568 0.0436 0.00 0 0 0 0 0 1 -360 360;

15 16 0.0067 0.005 0.00 0 0 0 0 0 1 -360 360;

15 17 0.0077 0.0059 0.00 0 0 0 0 0 1 -360 360;

17 18 0.0086 0.0569 -0.002 0 0 0 0 30 1 -360 360; %b is the inductive shunt loss of the trafo

18 19 4.2675 3.2719 0.00 0 0 0 0 0 1 -360 360;

];

%%----- OPF Data -----%%

%% generator cost data

% 1 startup shutdown n x1 y1 ... xn yn

% 2 startup shutdown n c(n-1) ... c0

mpc.gencost = [

1 0 0 1 0;

1 0 0 1 0;

];

**Run\_PF\_Banshee.m**

Name = 'Feeder1BansheeSimple';

% Name = 'Feeder1Banshee';

% Name = 'Feeder1BansheeNosnubbers';

% Name = 'Feeder1BansheeFULL';

clc

mpopt = mpoption('pf.fd.max\_it',100,'pf.alg','FDXB');

runpf(Name,mpopt)